

What is claimed is:

1. A magnetic levitation (maglev) stage apparatus, comprising:  
a platen having an upper surface capable of supporting a workpiece;  
a set of magnet arrays arranged on a bottom surface of the platen;  
first and second side magnet arrays arranged on respective opposite first and  
second sides of the platen;  
a support frame at least partially surrounding the platen on the first and second  
sides and the bottom surface;  
a plurality of motor coils arranged on the support frame so as to be in operable  
communication with the set of magnet arrays and the first and second side magnet  
arrays; and  
wherein the set of magnet arrays and first and second side magnet arrays and  
the plurality of motor coils are operable to magnetically levitate the platen within the  
support frame and move the platen in up to six degrees of freedom (DOF).
2. The apparatus of claim 1, wherein the set of magnet arrays includes first,  
second and third magnet arrays.
3. The apparatus of claim 2, where the first, second and third magnet arrays  
are arranged at the apexes of an imaginary triangle centered about an axis passing  
through a center-of-gravity of the platen.
4. The apparatus of claim 1, wherein the support frame is U-shaped.
5. The apparatus of claim 1, wherein the platen is monolithic.
6. The apparatus of claim 1, wherein the platen comprises a material  
selected from the group of materials consisting of: carbon fiber, Zerodur, ceramic and  
aluminum.
7. The apparatus of claim 1, wherein the platen upper surface is sized to  
support a 300 mm semiconductor wafer.
8. The apparatus of claim 1, wherein the motor coils comprise linear motors.

9. The apparatus of claim 8, wherein the linear motors include Lorentz force planar linear motors.

10. The apparatus of claim 2, wherein the first, second and third magnet  
5 arrays each have a long axis that is oriented in a first direction.

11. The apparatus of claim 10, wherein the first and second side magnet arrays each have a long axis that is oriented in the first direction.

10 12. The apparatus of claim 1, further including a mirror system fixed to the platen and adapted to reflect light from one or more mirrored surfaces.

13. The apparatus of claim 12, wherein the mirror system is formed integral with a chuck residing atop the platen upper surface.

15 14. The apparatus of claim 12, wherein the mirror system is optically contacted to the platen surface.

20 15. The apparatus of claim 12, further including one or more interferometers in optical communication with the mirror system to provide data pertaining to the state of the platen relative to a reference position.

25 16. The apparatus of claim 1:  
wherein the set of magnet arrays, first and second side magnet arrays and the plurality of motor coils define a force loop to apply a force to the platen;  
wherein the one or more interferometers reside on a support structure define a measurement loop to measure the state of the platen; and  
wherein the force loop and the measurement loop are coupled.

30 17. The apparatus of claim 15, further including a stage controller connected to the motor coils and to the one or more interferometers.

18. The apparatus of claim 17, wherein the stage controller is connected to or is part of a main controller of a photolithography system.

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19. The apparatus of claim 1, further including one or more rails that movably support the support frame.

20. The apparatus of claim 19, further including actuators and bearings  
operatively coupled to the one or more rails to provide a force to move the support  
frame over the one or more rails.

21. The apparatus of claim 1, wherein at least one of the motor coils includes  
a cooling line.

22. The apparatus of claim 1, further including:  
first and second counterweights arranged adjacent respective first and second  
outer sides of the support frame and adapted to move in opposition to the platen.

23. The apparatus of claim 22, wherein the first and second counterweights  
are operatively coupled to first and second bearings and first and second counterweight  
actuators to provide a force to move the counterweights.

24. The apparatus of claim 22, wherein the first and second counterweights  
have equal or substantially equal mass.

25. The apparatus of claim 22, wherein the platen has a mass and the first  
and second counterweights each have a mass that is substantially equal to half of the  
platen mass.

26. The apparatus of claim 22, wherein the first and second counterweights  
are adapted to move parallel to the first and second outer sides of the support frame.

27. The apparatus of claim 23, wherein the first and second bearings are air  
bearings.

28. The apparatus of claim 23, wherein the first and second counterweight  
actuators comprise linear motors.

29. The apparatus of claim 23, further including a stage controller connected

to the motor coils and to the first and second counterweight actuators.

30. The apparatus of claim 22, further including a mirror system fixed to the platen and adapted to reflect light from one or more mirrored surfaces.

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31. The apparatus of claim 30, wherein the mirror system is formed integral with a chuck residing atop the platen upper surface.

32. The apparatus of claim 30, further including one or more interferometer  
10 systems in optical communication with the mirror system to provide data to a stage controller pertaining to a state of the platen relative to a reference position.

33. The apparatus of claim 32, wherein the stage controller is further  
15 connected to the motor coils and the first and second counterweight actuators to control the state of the platen.

FIG. 10

34. The apparatus of claim 1, further including:  
a projection lens arranged adjacent the upper surface of the platen;  
a reticle stage arranged adjacent the projection lens and opposite the platen for  
20 supporting a reticle; and  
an illumination system arranged adjacent the reticle to illuminate the reticle so as to form an image of the reticle on the workpiece when supported by the platen upper surface.

35. The apparatus of claim 22, further including:  
a projection lens arranged adjacent the upper surface of the platen;  
a reticle stage arranged adjacent the projection lens and opposite the platen for  
supporting a reticle; and  
an illumination system arranged adjacent the reticle to illuminate the reticle so as  
30 to form an image of the reticle on the workpiece when supported by the platen upper surface.

36. A method of moving a workpiece supported by a platen, comprising:  
arranging a plurality of magnet arrays on one or more of the platen surfaces so  
35 that the magnet arrays are arranged symmetrically about the center of gravity of the

platen;

providing motor coils on a support frame that partially surrounds the platen; and  
operatively coupling the motor coils one to each magnet array so that one or  
more forces may be applied to the platen along one or more axes passing through a  
center of gravity of the platen to move the platen in up to six degrees of freedom.

37. The method of claim 36, further including:

activating one or more of the motor coils so as to move the platen in one or  
more of the six degrees of freedom.

38. The method of claim 36, including arranging counterweights adjacent the  
platen, the counterweights being movable in opposition to movement of the platen.

39. The method of claim 38, further including moving the counterweights in  
opposition to movement of the platen.

40. The method of claim 38, including moving the counterweights in a single  
degree of freedom.

41. The method of claim 35, further including movably supporting the support  
frame by one or more rails.

42. The method of claim 41, further including moving the support frame along  
the one or more rails.

43. The method of claim 38, further including movably supporting the support  
frame by one or more rails.

44. The method of claim 43, further including moving the support frame along  
the one or more rails.

45. The method of claim 36, further including interferometrically monitoring  
the state of the platen and providing data concerning the state of the platen to a stage  
controller.

46. The method of claim 38, further including interferometrically monitoring the state of the platen and providing data concerning the state of the platen to a stage controller.

47. The method of claim 39, further including moving the movable counterweights using bearings and actuators.

48. A method of patterning a photosensitive wafer, comprising:  
supporting the photosensitive wafer on the maglev stage apparatus of claim 1;  
repeatedly illuminating a reticle with radiation having a wavelength that activates the photosensitive wafer;  
forming an image of the reticle at the wafer for each repeated illumination; and  
moving the wafer on the maglev stage in up to six degrees of freedom so as to form an exposure field on the wafer for each image.

49. A method of patterning a photosensitive wafer, comprising:  
supporting the photosensitive wafer on the platen of the maglev stage apparatus of claim 22;  
repeatedly illuminating a reticle with radiation having a wavelength that activates the photosensitive wafer;  
forming an image of the reticle at the wafer for each repeated illumination;  
moving the platen of the maglev stage in up to six degrees of freedom so as to form an exposure field on the wafer for each image; and  
moving the counterweights in opposition to the movement of the platen.

50. A platen for a magnetic levitation stage, comprising:  
a carbon fiber base having a grid structure with an open end; and  
a sheet of a first thermally stable material fixed to the open end to form a platen upper surface.

51. A platen according to claim 50, further including a mirror system of a second thermally stable material fixed to the platen upper surface.

52. The platen of claim 50, wherein the grid structure is formed in a rectangular array comprising carbon fiber sheets.

53. The platen of claim 51, wherein the mirror system is optically contacted to the platen upper surface.

54. The platen of claim 50, further including a chuck formed from a third thermally stable material arranged atop the platen upper surface.

55. The platen of claim 50, further including a workpiece lifting system arranged in the platen, the workpiece lifting system including lifting pins that pass through holes in the platen upper surface and that extend to the chuck upper surface, the lifting pins being vertically movable to lift a workpiece arranged on the chuck upper surface.

56. The platen of claim 51, wherein the first and second thermally stable materials are the same.

57. The platen of claim 56, wherein the first and second thermally stable materials comprise ZERODUR®.

58. The platen of claim 54, wherein the first, second and third thermally stable materials are the same.

59. An interferometer system for a magnetic levitation (maglev) stage, comprising:  
a mirror system attached to a platen magnetically supported within a support frame, the mirror system including a first horizontal mirror;  
a second horizontal mirror formed on a stable support structure;  
an optical system mounted to the support frame and optically coupled to the first and second horizontal mirrors along respective first and second optical paths; and  
a light source optically coupled to the optical system for providing an input beam into the optical system to produce a return beam that includes positional information about the platen relative to the support structure.

60. The system of claim 59, wherein the light source includes a HeNe laser.

61. The system of claim 59, wherein the light source is capable of receiving

the return beam.

62. A method of interferometrically measuring the position of a platen in a magnetic levitation (maglev) stage, comprising:

5 reflecting a first light beam from a first horizontal mirror attached to a movable platen capable of supporting a workpiece;

reflecting a second light beam from a second horizontal mirror attached to a stable support structure;

10 interfering the first and second light beams using an optical system to obtain a third return beam that includes information about a state of the platen relative to a reference.

63. The method of claim 62, including providing the first and second light beams from a light source optically coupled to the optical system.

64. The method of claim 62, wherein the reference is the stable support structure.

65. The method of claim 64, further including sending the first light beam over a first optical path of length L1, sending the second light beam over a second optical path of length L2, and measuring the difference between the lengths L1 and L2.

66. A wafer lift assembly for a chuck comprising:  
a mounting plate fixed relative to the chuck, the mounting plate having a lower surface and a central aperture;  
25 a plurality of air-bushings attached to the mounting plate surrounding the central aperture;  
a movable plate having an upper surface arranged adjacent the lower surface of the mounting plate and movably coupled thereto by a voice coil actuator; and  
30 a plurality of pins extending upwardly from the movable plate upper surface and engaged by the air-bushings to be movable therewithin when the movable plate is moved by activation of the voice coil actuator.

67. The assembly of claim 66, wherein the voice coil assembly comprises a  
35 movable coil fixed to the movable plate and extending upwardly through the mounting



plate central aperture, and a magnet fixed to the mounting plate and surrounding the movable coil.

5        68.    The assembly of claim 66, wherein the mounting plate includes a plurality of outwardly extending arms, and one air-bushing is attached to each arm.

69.    The assembly of claim 67, further including a damper operatively coupled to the movable coil to damp the motion of the coil.

10       70.    The assembly of claim 67, further including a current amplifier connected to the voice coil to provide an amplified current signal thereto.